SPheno, a brief update on recent developments

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spectra, RGE codes schematic, ‘traditional approach’

Calculate $g_i(M_Z), Y_{t,b,\tau}(M_Z)$ at tree level.

Run to $M_X$ at 1-loop; Soft SUSY breaking boundary condition

Run to $M_{EW SB}; |\mu|$ and sparticle pole masses at tree level

SM and SUSY radiative corrections to $g_i(M_Z), Y_{t,b,\tau}(M_Z)$

Run to $M_X$; Soft SUSY breaking boundary condition

Run to $M_{EW SB}; |\mu|$ and (s)particle pole masses at loop level

Check if required precision is achieved

yes

no

Calculate additional observables
New: decoupling of all SUSY particles at $M_{\text{SUSY}}$  

- calculate $g_i^{\text{SM}}$ and $Y_i^{\text{SM}}$ at $m_Z$

- $\lambda^{\text{SM}}$: 1st iteration value for $m_H = 125$ GeV used,
  later iterations: calculated from $\lambda^{\text{SM}}(M_{\text{SUSY}})$ via RGE running to $m_Z$

- 2-loop SM-RGE up to $M_{\text{SUSY}}$ (usually $\sqrt{m_{\tilde{t}_1} m_{\tilde{t}_2}}$ with tree-level stop masses)

- $g_i^{\text{SM}}, Y_i^{\text{SM}} \rightarrow g_i^{\text{SUSY}}, Y_i^{\text{SUSY}}$
  resummation of large $\tan \beta$ effects using A.Crivellin et al. arXiv:1103.4272

- from here same procedure to get soft parameters at $M_{\text{SUSY}}$ but start SUSY RGE running, if necessary, from $M_{\text{SUSY}}$

- match at $M_{\text{SUSY}}$ $m_{h}^{\text{MSSM}} = m_{H}^{\text{SM}}$ to get $\lambda^{\text{SM}}$ (see also talk by Alexander Voigt)
  in SPheno: at the two-loop level
  - 1-loop: complete diagramatic calc. including $p^2$-dep.
  - 2-loop SUSY calc.: routines from Pietro
    $O(\alpha_t \alpha_s + \alpha_b \alpha_s + (\alpha_t + \alpha_b)^2 + \alpha_b \alpha_T + \alpha_T^2)$
  - 2-loop SM calc.: S.P. Martin, D.G. Robertson, arXiv:1407.4336, $O(\alpha_t \alpha_s)$ with $p^2 = 0$

- 2-loop SM-RGE down to $m_t$ to re-calculate $m_H$ at the 2-loop level.
Comparision with SUSYHD 1.0.2, mSUGRA scenarios

\[ A_0 = -2M_0 \]

\[ A_0 = 2M_0 \]

\[ A_0 = 0 \]

\[ M_{1/2} = M_0, \tan \beta (M_{SUSY}) = 10, \mu > 0 \]

\[ m_h : \text{SPheno standard, but using SM RGEs up to } M_{SUSY} = \sqrt{m_{\tilde{t}_1} m_{\tilde{t}_2}} \]

\[ m_h : \text{matching } m_{h}^{\text{MSSM}} = m_{H}^{\text{SM}} \text{ at } M_{SUSY}, \]

running \( \lambda_{\text{SM}} \) to \( m_t \)

\[ m_h : \text{SUSYHD handing over all parameters at } M_{SUSY} \]

preliminary results
Comparision with SUSYHD 1.0.2, mSUGRA scenarios

\[
A_0 = -2M_0
\]

\[
A_0 = 2M_0
\]

\[
A_0 = 0
\]

\[M_{1/2} = M_0, \tan \beta (M_{SUSY}) = 40, \mu > 0\]

\[m_h: \text{SPheno standard, but using SM RGEs up to } M_{SUSY} = \sqrt{m_{\tilde{t}_1} m_{\tilde{t}_2}}\]

\[m_h: \text{matching } m_{h}^{\text{MSSM}} = m_{H}^{\text{SM}} \text{ at } M_{SUSY}, \]

\[\text{running } \lambda^{\text{SM}} \text{ to } m_t\]

\[m_h: \text{SUSYHD handing over all parameters at } M_{SUSY}\]

preliminary results
- include $O(\alpha_s^2)$ contribution to $m^\text{SM}_H$
- get an understanding of the differences between SPheno and SUSYHD results
- finish implementation of ‘traditional’ EFT approach at 2-loop level
- include split-SUSY
- include some high scale motivated large hierarchies, e.g.
  \[ m_\tilde{q} \simeq m_\tilde{g} \gg m_\tilde{t}, m_\tilde{b} \gg M_1, M_2, \mu \]
- however general multiple scale is not possible: even taking an effective model with 14 mass parameters (e.g. taking sfermion masses for first two generations equal but different for $\tilde{q}_L, \tilde{u}_R, \tilde{d}_R, \tilde{l}_L, \tilde{l}_L$) gives $14! \simeq 9 \cdot 10^{10}$ mass orderings! (expect about $10^5$ GB code)